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Automated Infusion Monitoring Device Using Arduino-Based IoT (Internet of Things)

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ABSTRACT

Efforts to improve healthcare services in the medical world are being made by implementing rapidly evolving Computer and Information Technology. In the medical field, particularly in infusion procedures, this is the most commonly used device. The function of infusion is to administer fluids or medication into the body through an intravenous route at a constant rate for a specific period. Infusion is performed for patients who urgently need medication or require a continuous and slow administration of fluids due to dehydration. However, during implementation in the field, issues may arise due to a lack of medical personnel and nursing errors, especially considering the ongoing Covid-19 conditions. An automated infusion monitoring device is one of the solutions created to ease the nursing process by monitoring and regulating the infusion flow rate through a monitor that displays real-time fluid volume in the nurse's area. The author employs an Arduino Mega 2560 as the data reader, a Load Cell sensor to measure the weight of the fluid in the infusion, a Servo to control the infusion flow rate, and an ESP module to connect to the server.

Keywords: Monitoring Tool; Infusion; Sensor Load Cell; Servo Arduino Mega 2560; ESP module

INTRODUCTION

Infusion liquid is the purification of wat.er through a distillation process. Infusion fluids (intravenous fluids) are stored in a sterile bag or bottle which will be flowed through a tube into a vein, the type and amount of fluid used will depend on the patient's condition, the availability of fluids and the purpose of giving intravenous fluids. In addition to providing fluids, infusion can also be done as an alternative to parenteral drug administration. Not all diseases require infusion. Doctors or nurses usually recommend infusion when a patient experiences a medical emergency that requires the drug to enter the body quickly. For example, someone lacks fluids (dehydration), has a heart attack, stroke, or poisoning.

When such a situation occurs, taking medication by mouth will not help relieve the patient's condition. The process of absorption of drugs through the mouth takes longer because they must be digested by the body before they enter the bloodstream. Meanwhile, the patient needs prompt treatment, because if not, his condition can get worse. The function of the infusion is very important for the patient, therefore, the infusion process must be carried out correctly to avoid the possibility of complications arising that can affect the patient's condition. In addition, controlling and monitoring the use of infusion fluids must be carried out routinely by nurses, where nurses must continuously check one by one the patient's infusion condition.

Time constraints, the distance between the patient room and the control room, as well as the limited number of medical personnel at the hospital or health center, can cause delays in treating patients. If the IV fluid runs out, the nurse must immediately replace it with a new one, but in some conditions that are not possible, the nurse sometimes does not have time to replace it immediately, and this can be bad for patients who need IV fluids. If this kind of situation persists for a long time due to problems in the hospital, the patient will be greatly affected.

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From the description above, the author tries to make a tool that can regulate the amount of liquid drops and monitor the remaining liquid through a monitor connected to the web in the nurse's room. The way this tool works is by detecting drops that are in the infusion chamber. The droplets are detected by an infrared LED light sensor and a photodiode(Nataliana et al., 2016). The voltage signal from the sensor is conditioned by the LM339 comparator IC(Sucipta et al., 2021). The ATmega8535 microcontroller is used as an I/O data processor from the comparator so that information from the monitored parameters can be displayed on the LED and LCD as well as a buzzer sound.

The buzzer notification and alarm system aims to control the limits that have been set for infusion fluids that have run out and are connected via wireless type nRF24L01 to the duty nurse's room so that the sound from the buzzer does not disturb the comfort of other patients (Prini, 2020). In addition, the design and manufacture of an automatic infusion system and digital drip control system with an LCD display were carried out. This tool uses an ATmega16 microcontroller to control the rotation of the motor as a clamp. The existence of this tool can make it easier for medical staff to manage infusion drops, so that medical staff do not need to manually adjust the number of infusion drops and can improve service to patients.

Several other tools are also used to help provide information to nurses about the condition of intravenous fluids, such as whether they will run out or the drip rate is according to a doctor's prescription. The method used in the development of this tool is the method of observation and engineering. The Load Cell functions to measure the volume of intravenous fluids, while the photodiode functions to measure the drip rate of intravenous fluids.

Monitoring the level of infusion fluids is carried out using NodeMCU and photodiode sensors as an effort to overcome delays by nurses in giving fluids to patients (Qurahman & Fitriani, n.d.), and can also overcome the problem of rising blood into the infusion tube and determine the condition of the level of infusion fluids. This allows nurses to make continuous observations of infusion conditions in the field.

This system designs a centralized monitoring system for infusion fluids. Some of the hardware components consist of a webcam, Raspberry Pi, and computer. The Raspberry Pi and computer are connected by a LAN cable for data transmission devices with a Client-server system using the TCP/IP protocol (Ratnasari et al., 2022). Meanwhile, the software consists of Raspbian OS, OpenCV as a programming library, and MySQL database which is used to store data.

LITERATURE REVIEW

A literature review is a critical, analytical summary and synthesis of the current knowledge of a topic. It should compare and relate different theories/research, findings, and so on, rather than just summarize them individually. It should also have a particular focus or theme to organize the review. In this section, the researcher can describe some of the related previous studies. Researchers can review the gaps in the research, then it can be used as a basis for research to be carried out(Zakaria & Qibthiyah, 2022).

Intravenous Therapy (Infusion)

Health experts explain the meaning or define intravenous therapy in various forms and varieties. The following is a summary of the meaning of intravenous therapy according to experts according to their respective perspectives: Intravenous therapy is the process of injecting sterile fluid through a needle directly into a patient's vein. This sterile liquid usually contains electrolytes such as sodium, calcium, and potassium, nutrients such as glucose, and vitamins or drugs (*IOT Based Smart Door Locked System Using Node*, 2022). In another definition, intravenous therapy is the administration of a certain amount of fluid into the body through a needle inserted into a vein (vein) to replace lost fluids or nutrients from the body. This therapy is used when the patient is unable to swallow, unconscious, dehydrated, or in shock (Samsono, 2022). In addition, it is also used to provide the salt needed to maintain electrolyte balance, or glucose needed for metabolic processes and provide medication (Sardana et al., 2019). The things that need to be considered in the provision of fluids and electrolytes:

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a. Water and electrolyte requirements in infants and children.Water needs (0-10 kg = 4 ml/kg/hour (100 ml/kg/day),10-20 kg = 40 ml + 2 ml/kg/hour each kg over 10 kg (1000 ml + 50 ml/kg/day each kg over 10 kg).,>20 kg = 60 ml + 1 ml/kg/hour every kg over 20 kg (1500ml + 20 ml/kg/day every kg over 20 kg).Potassium needs 2.5 mEq/kg/day. Sodium requirement 2-4 mEq/kg/day.
b. Water and electrolyte requirements in adults, The need for water is 30-35 ml/kg/day.Potassium needs 1-2 mEq/kg/day.Sodium requirement 2-3 mEq/kg/day
c. Factors that influence the increase in fluid requirements. Hyperventilation (excessive or too fast breathing). High ambient temperature. Excessive activity. High fever (body fluid requirements increase 12% for every 10ºC, if the temperature is >370ºC). Any abnormal loss of body fluids such as diarrhea or polyuria
d. Factors that affect the decrease in fluid requirements. Hypothermia (body fluid requirements decrease by 12% for every 10°C, if the temperature is <370°C). Very high environmental humidity. Oliguria (little urine production) or anuria (no urine output). Almost no activity.
e. Disturbances / problems meeting the needs of fluids.
   Dehydration is a symptom of a lack of external fluids that can occur due to decreased fluid intake and excess fluid expenditure in the body. Dehydration can cause fluid loss of 4 or 6 liters (Severe Dehydration) or loss of 2 or 4 Liters (Moderate dehydration). The following symptoms when dehydrated include sunken eyes, poor skin turgor, fast but weak heart rate, etc. The composition for giving serum sodium is 159-166 mEq/L (for severe dehydration) and the composition for giving serum sodium is 152-158 mEq/L (for moderate dehydration).
   Here's an easy way to calculate infusion drops per minute (TPM)(Sujiwa & Dianto, 2022):

$$\text{Drops per minute (macro)} = \frac{\text{amount of fluid injected(ml)}}{\text{Infusion duration (hours)x3}}$$

$$\text{Drops per minute (micro)} = \frac{\text{amount of fluid injected(ml)}}{\text{Infusion duration (hours)x3}}$$

Arduino Mega 2560

Arduino is a microcontroller-based board or open source electronic circuit board in which there is a main component, namely a microcontroller chip with the AVR type from the Atmel company (Randhwan & Gawade, 2023). The microcontroller itself is a chip or IC (integrated circuit) that can be programmed using a computer. The purpose of embedding a program on a microcontroller is so that the electronic circuit can read the input, process the input and then produce the desired output. So the microcontroller serves as the brain that controls the process of input and output of an electronic circuit

NodeMCU ESP8266

NodeMCU is an open source IoT platform and development kit that uses the Lua programming language to help manufacture IoT products or you can use sketch with the Arduino IDE (Gonzaga et al., 2022)(Samsono, 2022). NodeMCU also has a very small board, which is 4.83cm long, 2.54cm wide, and weighs 7 grams. In addition, NodeMCU also has a relatively affordable price, but despite its small size and affordable price, this board is equipped with wifi features and open source firmware. WiFi or Wireless Fidelity is a standard device used for wireless local network (WLAN) communication based on the IEEE 802.11 specification.

LCD (Liquid Cristal Display)

Electronic display is an electronic component that functions as a display of data, either characters, letters or graphics. LCD (Liquid Cristal Display) is a type of electronic display made with CMOS logic technology which works by not producing light but reflecting the surrounding light towards the front-lit or transmitting light from the back-lit. LCD (Liquid Cristal Display) functions as a display of data either in the form of characters, letters, numbers or graphics.

Load Cell Sensor

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Load Cell sensor is a type of load sensor that is widely used to convert loads or forces into changes in electrical voltage. The change in electric voltage depends on the pressure coming from the load. On the Load Cell sensor there is a strain gauge, which is an electronic component used to measure pressure. The strain gauge was confirmed to be a Wheatstone bridge circuit. Consists of four resistors arranged in series and parallel.

Modul HX711

The HX711 module is used to amplify the output signal from the sensor and will be converted from analog data to digital data then the measured data can be processed by the microcontroller (Primahayu et al., 2017). The HX711 module offers many conveniences. This module has 3 gain values, namely gian 32, 64 and 128. However, for this digital scale a gain of 128 is used by connecting the sensor output to channel A of the module. This module uses a "tow wire" interface, namely clock and data to communicate. To make it easier to read data from the HX711, a library has also been provided that can be used.

Servo Motor

The servo motor is a closed loop servo mechanism that uses position feedback to control its motion and final position. The input to the control is a signal (either analog or digital) that represents the commanded position for the output shaft. The motor is coupled with some type of position encoder to provide position and speed feedback. In the simplest case, only position is measured. The measured position of the output is compared to the command position, the external input to the controller. If the output position is different from that required, an error signal is generated which then causes the motor to rotate in either direction, as needed to bring the output shaft to the appropriate position. As the position approaches, the error signal decreases to zero and the motor stops.

METHOD

Planning Stages

The type of research used is cumulative research with experimental methods. By choosing this type of research, the authors consider this type to be very suitable for the research raised by the authors because they carry out the development of a tool and conduct research in the form of experiments on the author's research object

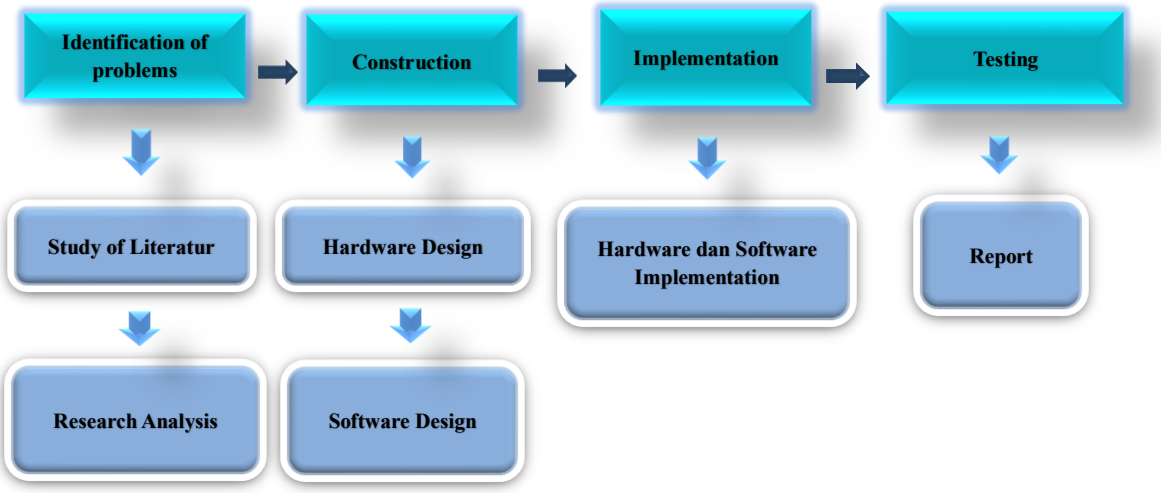


Fig.1. Framework

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The stages of the research carried out are as follows

a. Problem Identification
It is a study of existing problems, namely the problem of checking the condition of the patient's infusion fluids regularly to the patient's room. Then determine a solution to solve the problem by making an automatic infusion monitoring tool.
   a. Study of literature
   This literature and literature study was conducted to study theories related to the design of an IoT-integrated automatic infusion monitoring tool that will be made. At this stage we study how the Load Cell sensor works to detect the volume of the condition of the infusion fluid bag.
   b. Research Analysis
   Analysis of the research system is carried out by comparing existing theories and things that can affect the results of system performance

b. Construction
   a) Hardware Design
   The hardware design is an integrated series consisting of Arduino Mega 2560, Load Cell Sensor, HX711, ESP 8266 WiFi Module, 16x2 LCD, and Buzzer. The design carried out aims to detect the condition of the infusion fluid volume and give an alarm to the user when the infusion condition is almost used up.
   b) Software Design
   This is an Arduino Mega 2560 program designed to support hardware devices to work as desired.

c. Implementation hardware and software implementation
Implementation of hardware design on the Arduino Mega 2560 and implementation of software design in the form of the Arduino IDE program on the transmitting side and the webside on the receiving side.

d. System Testing
Testing the automatic infusion alarm system with wireless communication is carried out whether it is in accordance with the desired system. The report contains explanations relating to the research that has been carried out and also as documentation of the research.

System Design Stage

1. Analysis Phase
At this stage of the analysis, the authors conducted a direct survey of several related parties and conducted qualitative research using experimental methods. The authors found problems with the use of intravenous fluids due to a lack of medical personnel resources and carried out manual monitoring, which resulted in protracted problems.
2. Design Stage
   a. Dagram Blog
   Based on the blog diagram above, this study uses the Arduino Mega 2560 as the main microcontroller. Input from the built tool comes from the Load Cell sensor detector and the HX711 module which functions to read the load cell sensor in measuring the volume of infusion fluids. The load cell sensor will be placed on the modified infusion pole. The output of this tool is in the form of an LED light which will go off with predetermined parameters, when the infusion liquid is less than the maximum value, the sensor will read and send a signal to the Arduino which will produce an output which will be conveyed to the LED light which will light up, and for the LCD serves to display the results of data on the volume of fluids in

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the nurse's room. The ESP 8266 module will display data results from Arduino to the desktop in the nurse's room which is connected to the WiFi network.

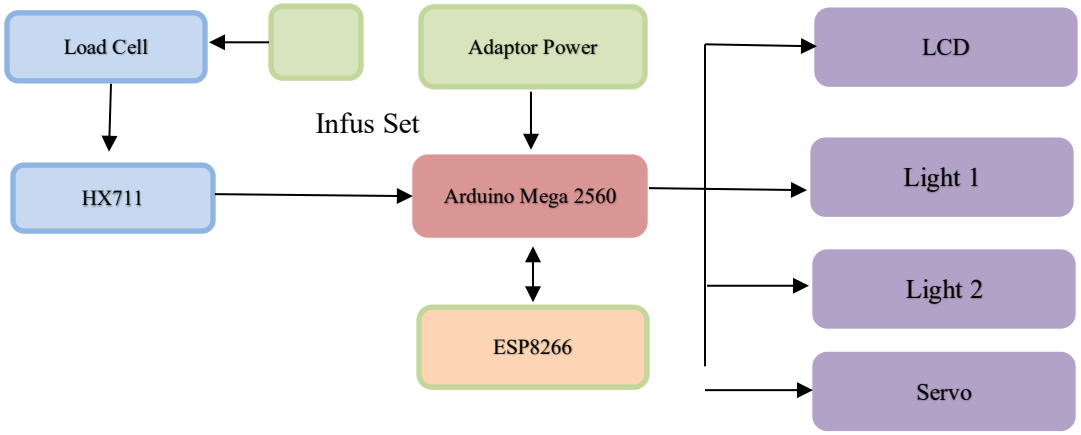


Fig.2 Blog Diagram

b. Wiring Diagrams

Wiring diagram is a picture of the wiring of the tool, which describes the position of the cable and symbols on the tool.

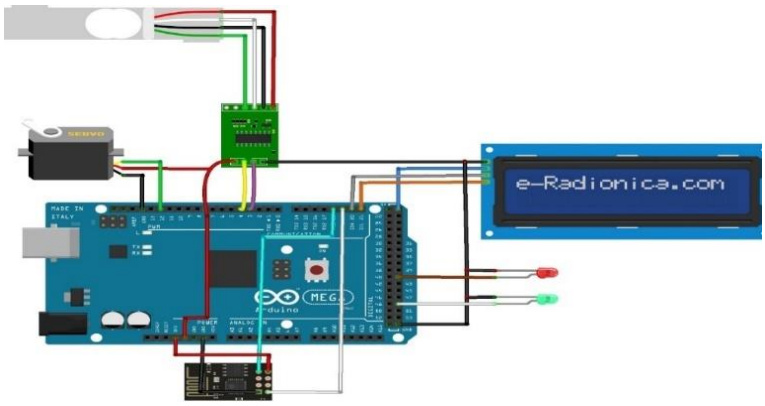


Fig. 3. Wiring Diagrams

Figure 3 illustrates the wire and symbol placements on the tool. It comprises the following connections:

1. LCD: SCL linked to SCL (pin 21) on the Arduino, SDA connected to SDA (pin 20) on the Arduino, GND connected to GND HX711, VCC connected to 5V.
2. Hx711: GND connected to LCD GND and Arduino, DT connected to Arduino pin 4, SCK connected to Arduino pin 3, VCC connected to 5V.
3. Servo: GND connected to Arduino GND, DT connected to pin 12, VCC connected to 5V.
4. Red Led: GND connected to GND Arduino, DT connected to pin 41.
5. Green Led: GND connected to GND Arduino, DT connected to pin 49.
6. Esp8266: RX connected to Arduino TX (pin 18), TX connected to Arduino RX (pin 19), GND connected to Arduino GND, VCC connected to 3V.

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RESULT

Tool Description

The infusion monitoring tool is not the use of the latest technology, although the authors have added a series and new features to this infusion monitoring tool. It is hoped that this tool will be useful for medical nurses. The use of an infusion monitoring device basically makes it easier for users to monitor the condition of the infusion used by the patient. The existence of this tool can reduce the risk of running out of intravenous fluids which can affect the patient's condition.

Final Results of Applications and Tools

1. Login page to validate the user to enter the infusion monitoring application. Login is the first step that must be done by a user or officer who has authority before being able to access and manage all data related to the system.
2. Control Menu Page

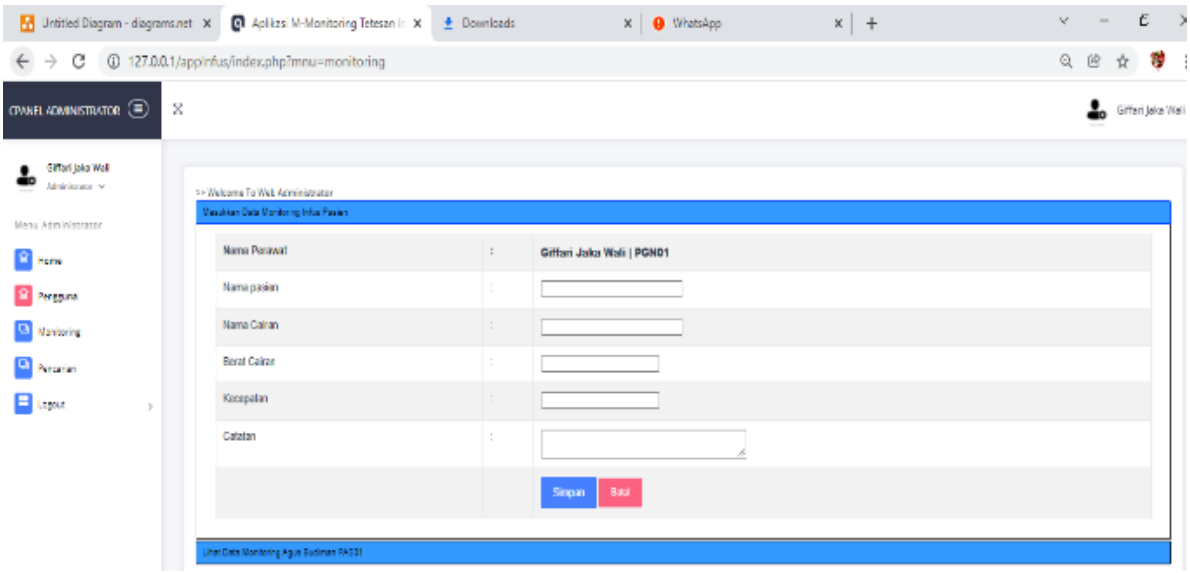


Fig.4. Control Menu Page

The control menu display is used to control manually entering patient data with what the patient is suffering from. The nurse only needs to input the patient's name, the name of the liquid used, the weight of the liquid, the speed at which the liquid drops, and enter the symptoms the patient is suffering from in the notes column then press save to save the data that has been made

3. Infusion Fluid Monitoring Prototype



Fig. 5. Infusion Fluid Monitoring Prototype

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is a miniature prototype monitoring of infusion fluids. In this miniature, all components have been installed, such as the Arduino Mega 2560, load cell sensor, servo, esp8266, LCD, red and green LEDs, and others.

4. Infusion Fluid Monitoring Prototype
   is a miniature prototype monitoring of infusion fluids. In this miniature, all components have been installed, such as the Arduino Mega 2560, load cell sensor, servo, esp8266, LCD, red and green LEDs, and others.

Use of Website Applications and Tool Functions

The following is the use of an automatic infusion fluid monitoring website that will be used by admins or nurses to carry out control and monitoring.

Potential and Opportunity

The existence of an IOT-based automatic infusion fluid monitoring tool (Internet of Things) can help relieve the operational performance of all medical personnel in monitoring infusion fluids. Therefore infusion monitoring can help provide information about the volume of infusion fluids and regulate the drip rate of infusion fluids.

The admin is the first person to input new user data and then medical staff can monitor patients. The existence of an infusion monitoring device can ease the responsibility of medical personnel because it can provide regular notification of the condition of infusion fluids

DISCUSSIONS

To initiate the use of this tool, you must first access the website and navigate to the infusion fluid monitoring home menu. Once there, you will need to log in using your registered username and password provided by the administrator. After successfully logging in, utilize the control menu to select the monitoring option. For user access, simply choose the monitoring menu and click on "Select monitoring" to proceed. This action will display the patient infusion monitoring data input menu. You can then manually input patient data along with a description of their condition.

When using the monitoring menu for nurses, selecting the bar below will prompt the appearance of the patient data monitoring menu. If any data changes are required, nurses can easily navigate back to the menu and enter the patient's infusion monitoring data accordingly. If detailed data on the use of infusion fluids is needed, the nurse can access it by pressing the print feature on the patient monitoring data menu. To operate the tool, first connect the 5V Power Supply to the mains. Allow a few moments for the device to establish a connection with the registered internet network. Once successfully connected, the LCD will display a welcome message and show the weight of the infusion fluid, indicating that the equipment is ready for use.

CONCLUSION

This research successfully developed an automated infusion monitoring device using Arduino-based Internet of Things (IoT) technology. The device enables more efficient and accurate infusion monitoring, with the capability to collect real-time data and transmit it through the internet network. The utilization of Arduino as the foundational platform provides flexibility and ease in integrating various sensors and devices for monitoring purposes. With its automation feature, this device can assist medical personnel, including nurses, in monitoring patients more effectively and reducing the potential for human errors. The IoT technology implemented in this device holds the potential for integration with broader healthcare systems, enabling more comprehensive patient data collection and integration with hospital management systems. Nevertheless, this research may also have some limitations, such as the need for ongoing optimization of

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device performance and stability, as well as addressing security issues that may arise due to internet connectivity. In conclusion, this research successfully developed a device that holds the potential to make a positive contribution efficient patient infusion monitoring, thanks to the application of IoT technology and the Arduino platform

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